

## DETERMINATION OF SHORT-TERM EFFECTS OF WILD FIRE ON SOIL PROPERTIES AND NITROGEN MINERALIZATION IN TURKISH PINE (*Pinus brutia* Ten.) IN TURKEY (THE CASE OF SARIÇİÇEK SUB-DISTRICT DIRECTORATE)

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**Abstract.** Forest fires are one of the factors that play an important role in both global warming and nutrient accumulation in soils. The level of these effects varies according to the severity and intensity of the fire. This study was conducted to determine the one-year effects of fire on soil properties and nitrogen mineralization in Turkish Pine stands exposed to low-intensity surface fire that naturally occurred at the Sarıçiçek region the Vezirköprü district of Samsun province in 2014, in Turkey. To this end, six sampling areas were selected from both burned and unburned (control) areas in the sections. Soil samples were taken from a depth of 0-5 cm and 5-10 cm. Nitrogen mineralization was determined by the land incubation in 3 periods (April-July-October, 2014) on-site holding method. Among soil properties, texture, pH, organic matter, total nitrogen, bulk density and carbon (C) / nitrogen (N) ratio analyses were assessed. As a conclusion, it was observed that significant differences occurred in soil properties and nitrogen mineralization temporarily. Average nitrogen mineralization at a depth of 0-10 cm over the one- year period was found to be 23.56 kg /ha in the burned areas and 25.2 kg/ha in the control areas. As a result of the study, it was concluded that the fire was more effective, especially at a depth of 0-5 cm in regards to changing the soil properties. Nitrogen mineralization at a depth of 0-5 cm was greater in the burned areas compared to controls. It was determined that especially low-intensity fires were not effective toward the lower depth levels.

**Keywords:** *global warming, nutrient accumulation, low-intensity fire, nitrogen mineralization, surface fire*

### Introduction

Although forest fires have been regarded as natural disasters for many years, they have been considered to be a part of an ecological system in recent years. Along with the understanding of the dynamics of the ecosystem, natural resource managers can preserve the natural structure of the ecosystem and also ensure its transformation into different structures and compositions by using controlled and purposeful burning applications, which are practical, economical and natural methods, as a management tool (Franklin, 1993; McKenney et al., 1994; Gauthier et al., 1996; James et al., 2018; Quigley et al., 2020).

Indeed, it has been determined in many studies that fires are not just natural events that cause damage. If there were no fires in nature, all forest areas would become monocultures, all kinds of diseases and insect damages would increase and spread due to the excess accumulation of living and dead vegetation, and there would be the excessive accumulation of flammable materials and infertility. Because of all these beneficial aspects of fires, the fire has now become one of the key elements in the management of renewable natural resources (Wright and Bailey, 1982; Alcañiz et al., 2016, 2018).

Forest fires are an important factor in natural forests and bushes, and they are also useful in the management of afforestation in prescribed burning (Kaye et al., 1999; Johnson et al., 2008; Boerner et al., 2009; Fonseca et al., 2017; Fuentes et al., 2018). A  $5.1 \times 10^8$  ha forest area is burned mostly due to human activities every year in the world in the global process (Goldammer, 1993; Caldararo, 2002). The direct and indirect effects of forest fires on soil properties in the forest ecosystems have been extensively investigated (Fernandez et al., 1997; Mabuhay et al., 2003; Boerner et al., 2009). Some of these studies explain the effects of fires on soil organic carbon and nitrogen, which determine the soil quality.

Microbial biomass plays an essential role in nitrogen mineralization and carbon sequestration (Hernandes et al., 1997; Jensen et al., 2001; Ilstedt et al., 2003). Nevertheless, these studies do not fully indicate whether the effects of fire on microbial biomass are negative, positive or neutral (Choromanska and DeLuca, 2001; Mabuhay et al., 2003; Liu et al., 2007; Rutigliano et al., 2007; Rodriguez et al., 2009). Most of the studies indicate that there is a strong linear relationship between organic matter and soil respiration and nitrogen mineralization. In other words, the organic matter that is changeable in the soil is used in soil respiration and nitrogen mineralization (Wang et al., 2003; Haynes, 2005; Laik et al., 2009). Fire effectively changes soil respiration and nitrogen mineralization in the long or short term. It also has effects on the physical, chemical, and biological properties of the soil, such as soil moisture, nutrient availability, and microbial activities (DeLuca and Zouhar, 2000; Le Duc and Rothstein, 2007; Hamman et al., 2008). Hamman et al. (2008) indicated that prescribed burning decreased soil moisture in coniferous species, increased soil pH and significantly changed the nitrogen mineralization.

Some studies have revealed that forest fires are effective in soil respiration and nitrogen mineralization (Fernandez et al., 1997; Choromanska and DeLuca, 2001; Guerrero et al., 2005; Boerner et al., 2006). However, others state that their effects are inconsistent. Namely, while DeLuca and Zouhar (2000) stated that potential mineral nitrogen increased immediately after the fire, Weston and Attiwill (1990) determined that it decreased.

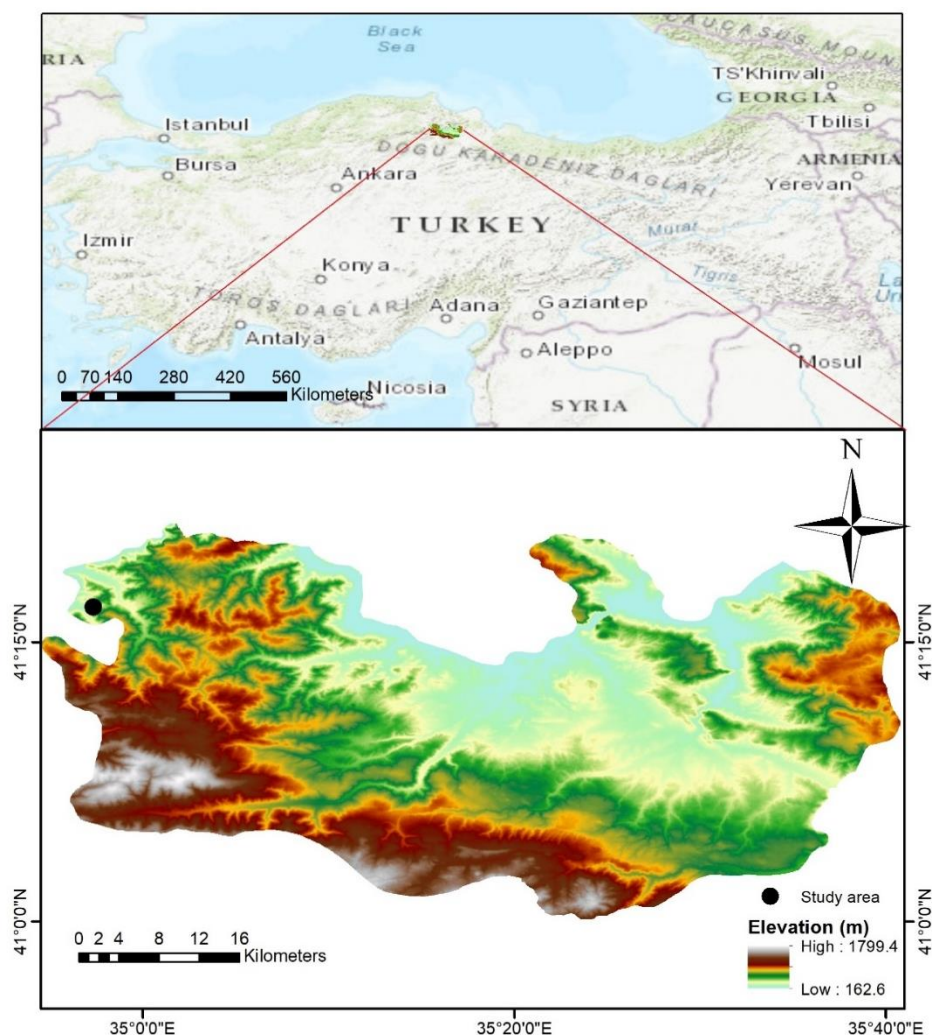
Wang et al. (2012) indicated that organic matter decreased by 20.3% and nitrogen increased by 13.1% after the fire compared to control areas. However, they reported that the fire had no significant effect on soil organic matter and total nitrogen. They stated that the highest effect of the fire occurred within the first three months after the fire. In the study, it was also revealed that the forest type and natural fires in natural zones affected total nitrogen and total organic carbon. Accordingly, while organic matter and nitrogen decreased by 25.3% and 22.7% in coniferous species, they increased by 28.0% and 28.7% in hardwood species. While fire decreased soil respiration by around 13.5 %, it decreased nitrogen mineralization by approximately 21.8%. The effect of fire on nitrogen mineralization changed as the depth of soil changed, and there was a decrease by 23.8% at a depth of 0-5 cm.

The objectives of this study were to determine the N mineralization potential, soil respiration and some soil properties in Turkish Pine (*Pinus brutia* Ten.) stands exposed to natural fire in Sarıçiçek region in Vezirköprü district of Samsun province under field conditions, in Turkey.

## Material and Method

### Site description

Study area is located Vezirköprü, Samsun in the northern Turkey ( $41^{\circ} 14' 21''$  N -  $34^{\circ} 54' 13''$  E). This study was conducted in average 60 years old, with 30% canopy cover Turkish pine (*Pinus brutia* Ten.) stands exposed to natural fire in the section numbered 28 within the boundaries of Sarıççek Forest Sub-District Directorate within Amasya Regional Forest Directorate, Vezirköprü Forest Management Directorate in Turkish Pine stands exposed to natural fire and the control areas next to them (Figure 1). The fire damaged approximately 1 hectare of the forest area. Average slope of the study area was 20-30% and its aspect was southwest.



**Figure 1.** Location (a) (green color) and Digital Elevation Model (ARC-GIS 9.2) (b) of the study area

At the meteorological station where the research area is located, the highest average temperature occurs in July and August by  $21.2^{\circ}\text{C}$ , the lowest average temperature occurs in January by  $0.9^{\circ}\text{C}$ , the annual average temperature is  $11.5^{\circ}\text{C}$ , the lowest average humidity occurs in July by 60.3%, the highest average wind speed occurs in July by

2.2 m/sec, the lowest average precipitation occurs in August by 14 mm, the highest average precipitation occurs in May by 55.1 mm, and the annual precipitation is 415.6 mm.

With regard to geological structure, the Central Black Sea region consists of volcanic rocks such as basalt, andesite and granite. The soil type is generally sandy, clay soil (Anonymous, 2009).

The research area is located in the Euro-Siberian (Euxine) flora area, which is one of Turkey's three major flora regions (Anşin, 1983).

It was determined that the research area was composed of coniferous species (Scotch pine, Corsican pine, and *Pinus brutia*) and hardwood species (beech and hornbeam). While there are pure beech stands in the area, it was determined that they were also mixed with Scotch pine tree species.

### ***Determination experimental plots method***

The experimental plots were determined by carrying out a preliminary study on Turkish pine areas exposed to natural fire in February 2014 one month after the fire. A total of 12 experimental plots, including six plots from the burned area and six plots from the control areas, were determined (*Figure 2*). As the size of the experimental plots, 15 m \* 20 m = 300 m<sup>2</sup> areas were chosen.



A



B

***Figure 2. Views of burned area (A) and unburned area (B)***

### ***Taking soil samples***

Twenty-four soil samples (6 burned \* 2 depths= 12, 6 controls \* 2 depths=12, Total 24) were taken from the fire and control areas in every period. Soil sampling was performed in every three months (April 2014, July 2014, and October 2014). Analyses were conducted on a total of 72 soil samples. These soil samples were placed in double plastic bags, labeled and brought to the laboratory environment.

### ***Net mineralization test***

For nitrogen mineralization, the samples were taken from a depth of 0-5 cm and 5-10 cm from each sampling areas. The wet weights were measured by a digital weight meter. The samples were passed through 4 mm standard steel sieves, and some of them were placed in polyethylene bags, labeled, incubated under field conditions and then buried in the soil for net mineralization measurement. Some of the sieved soil was also labeled and brought to the laboratory to determine the actual mineral nitrogen. Mineralization measurements were conducted in three periods (April 2014 - July 2014, July 2014 - October 2014, and October 2014 - April 2015). Nitrogen mineralization was measured in a total of 432 soil samples, including mineralization and actual (initial) mineralization in field incubation.

### ***Laboratory methods***

The samples taken from the study area to the laboratory environment were dried until they were air-dried. The roots and stones of each sample were removed, labeled and placed in plastic bags. The dried soil samples were crushed in a mortar and sieved using a 2 mm standard steel sieve. The sieved samples were labeled and prepared for analysis. The texture analysis of the soils was performed based on the Bouyoucos hydrometer method (Gülcur, 1974). The pH of soil samples was determined by the glass electrode method using an Inolab pH level I pH meter (Gülcur, 1974). The organic matter in the soil was determined by the modified Walkley - Black wet decomposition method (Gülcur, 1974; Kacar, 2009). The Kjeldahl wet digestion method was used for the determination of total nitrogen (Steubing, 1965; Ozturk et al., 1997). The carbon/nitrogen ratio (C/N) is the ratio of organic carbon and organic nitrogen measured in percent to each other. The samples taken from the field with a soil bulk density cylinder were dried at 105 °C, and the moisture in the soil was removed. After weighing the soil in the bulk, the bulk density was calculated by dividing it by cylinder volume (Gülcur, 1974).

### ***Determination of mineral nitrogen***

In the samples taken from the beginning of April 2014, actual mineral nitrogen and net mineral nitrogen yields were calculated. Mineral nitrogen was identified in a total of 432 soils, 144 soils in each period, at both depth levels. The micro-distillation method was used for the determination of mineral nitrogen in the soil (Bremner and Keeney, 1965; Gerlach, 1973; Güleriyüz, 1992). The determination of mineral nitrogen consists of two stages. In the first stage, the amount of ammonium ( $\text{NH}_4^+\text{-N}$ ) in the soil is found, and the amount of nitrate ( $\text{NO}_3^-\text{-N}$ ) is determined in the second stage (Öztürk et al., 1997). The net amount of ammonium was calculated by the difference between the ammonium value measured in the samples taken at the end of the incubation period and the ammonium value measured in the samples taken at the beginning of the incubation. This calculation was made for three periods. The annual net  $\text{NH}_4$  yield was found by summing the ammonium yields obtained over three periods (*Eq. 1*).

$$\text{Net NH}_4 = \text{End of incubation NH}_4 - \text{Initial NH}_4 \quad (\text{Eq.1})$$

The net amount of nitrate was calculated by the difference between the nitrate value measured in the samples taken at the end of the incubation period and the nitrate value measured in the samples taken at the beginning of the incubation. This calculation was

made for three periods. The annual net  $\text{NO}_3$  yield was found by summing the nitrate yields obtained over three periods (Eq.2).

$$\text{Net NO}_3 = \text{End of incubation NO}_3 - \text{Initial NO}_3 \quad (\text{Eq.2})$$

Net mineral nitrogen yield was calculated by adding the sum of the net ammonium yield and net nitrate yield.

The statistical analysis was performed on the data obtained by using the SPSS 16.0 and Windows statistical software. The analysis of variance was done to determine whether there was a temporal difference in the fire and control areas, and Tukey's test was carried out to determine where the differences were. The difference between the fire and control areas in terms of soil properties was determined by conducting the independent t-test. As a consequence of the tests, letters (such as A, B, AB, a, b) were provided as indicators of significance levels ( $P < 0.05$ ) and difference in the tables.

## Results and Discussion

### Results

The data obtained by some physical and chemical analyses on the soils are presented in *Tables 1 and 2*.

**Table 1.** Temporal change data of some soil properties of the soils at a depth of 0-5 cm

Soil Property	Sample Area	April 2014	July 2014	October 2014	Significance level
Sand	Control	73.70Aa	72.93Aa	77.39Aa	0.207
	Fire	71.02Aa	71.47Aa	68.68Ab	0.185
	Significance level	0.300	0.472	<b>0.001</b>	
Clay	Control	11.27Aa	6.89Ba	6.19Ba	<b>0.000</b>
	Fire	12.74Aa	8.97Aa	7.49Aa	0.131
	Significance level	0.586	0.182	0.241	
Silt	Control	15.03Aa	20.18Aa	16.42Aa	0.092
	Fire	16.24Aa	19.56ABa	23.82Bb	<b>0.037</b>
	Significance level	0.702	0.786	0.003	
pH	Control	6.76Aa	7.14Aa	7.17Aa	0.170
	Fire	7.03Aa	7.19Aa	7.46Aa	0.061
	Significance level	0.156	0.806	0.239	
Organic Matter	Control	7.91Aa	8.01Aa	9.27Aa	0.336
	Fire	9.34Aa	8.48Aa	8.33Aa	0.263
	Significance level	0.143	0.595	0.229	
Total Nitrogen	Control	0.26Aa	0.26Aa	0.30Aa	0.297
	Fire	0.25Aa	0.24Aa	0.23Ab	0.601
	Significance level	0.744	0.444	<b>0.008</b>	
C/N ratio	Control	18.0Aa	18.2Aa	18.3Aa	0.880
	Fire	22.0Ab	20.9Ab	21.0Ab	0.222
	Significance level	<b>0.000</b>	<b>0.007</b>	<b>0.001</b>	
Bulk Density	Control	1.09Aa	0.99Aa	0.96Aa	0.126
	Fire	1.06Aa	0.92Aa	0.92Aa	0.149
	Significance level	0.511	0.136	0.680	



**Table 2.** Temporal change data of some soil properties of the soils at a depth of 5-10 cm

Soil Property	Sample Area	April 2014	July 2014	October 2014	Significance level
Sand	Control	64.5Aa	67.3ABa	73.8Ba	<b>0.023</b>
	Fire	65.5Aa	68.9Aa	66.4Ab	0.594
	Significance level	0.773	0.621	<b>0.029</b>	
Clay	Control	18.5Aa	13.5ABa	7.8Ba	<b>0.001</b>
	Fire	14.9Aa	10.2Aa	9.5Aa	0.053
	Significance level	0.288	0.125	0.088	
Silt	Control	17.04Aa	19.23Aa	18.44Aa	0.623
	Fire	19.56Aa	20.88Aa	24.12Aa	0.254
	Significance level	0.150	0.588	0.062	
pH	Control	6.43Aa	7.20Aa	7.30Aa	0.060
	Fire	6.57Aa	6.90Aa	7.48Ba	<b>0.000</b>
	Significance level	0.726	0.091	0.507	
Organic Matter	Control	4.31Aa	5.73ABa	7.24Ba	<b>0.048</b>
	Fire	6.08ABb	4.86Aa	6.97Ba	<b>0.026</b>
	Significance level	<b>0.030</b>	0.411	0.787	
Total Nitrogen	Control	0.14Aa	0.16Aa	0.19Aa	0.134
	Fire	0.16ABa	0.14Aa	0.18Ba	<b>0.019</b>
	Significance level	0.122	0.448	0.549	
C/N ratio	Control	18.1Aa	21.2Aa	21.6Aa	0.042
	Fire	21.6Ab	20.6Aa	22.1Aa	0.306
	Significance level	0.013	0.605	0.689	
Bulk Density	Control	1.12Aa	1.21Aa	1.15Aa	0.640
	Fire	1.10Aa	1.15Aa	1.14Aa	0.703
	Significance level	0.522	0.346	0.964	

According to these data, at a depth of 0-5 cm, while soil properties such as sand, nitrogen content and bulk density generally decreased with the fire, properties such as clay, silt, pH, organic matter and C/N ratio increased. Along the passage of time over the fire, sand, clay, organic matter, nitrogen, and bulk density decreased. This decrease or increase was not found to be statistically significant, except for the silt in the fire area. The difference in soil properties values between the burned area and unburned area was not generally statistically significant. The increase or decrease in soil properties were at very low levels.

At a depth of 5-10 cm, while soil properties such as sand, silt, pH, and C/N ratio generally increased with the fire, properties such as clay, organic matter, nitrogen, and bulk density tended to decrease. The difference in soil properties values between the burned area and unburned area at a depth of 5-10 cm was not statistically significant. The increase or decrease in soil properties was at very low levels. The temporal change in soils in the areas exposed to fire was found to be statistically significant in pH, organic matter, and nitrogen values.

Net nitrogen mineralization values are presented in *Table 3*. At a depth of 0-5 cm, while the amount of ammonium was lower in the fire areas than control areas, the amount of nitrate was higher. In the mineralization measurements performed in the burned areas,

while it was revealed that ammonium tended to decrease first and then to increase and finally to decrease compared to the control areas, there was an increase, and then an increase and finally a decrease in nitrate values. The total mineralization value at a depth of 0-5 cm was found to be low in the fire area only in the October 2014-April 2015 mineralization period. The total annual mineralization value was identified to be slightly higher in the fire area. The temporal change in the fire areas was determined to be significant in ammonium and total nitrogen mineralization ( $P < 0.05$ ). The difference in all mineral nitrogen values between the burned area and unburned area was found to be statistically insignificant ( $p > 0.05$ ).

**Table 3.** Mean net nitrogen mineralization values at a depth of 0-5 cm and 5-10 cm

	Sample Area	Depth	Measurement Period			Total Annual	Significance level
			April-July 2014	July-October 2014	October 2014- April 2015		
NH <sub>4</sub> (kg/ha)	Fire	0-5 cm	1.58Aa	1.59Aa	2.57Ba	5.74a	<b>0.008</b>
	Control		1.64Aa	1.53Aa	2.7Ba	5.87a	<b>0.010</b>
	Significance level		0.863	0.865	0.720	0.786	
NO <sub>3</sub> (kg/ha)	Fire	0-5 cm	2.14Aa	1.37Aa	2.43Aa	5.94a	0.208
	Control		1.44Aa	1.27Aa	2.57Ba	5.28a	<b>0.012</b>
	Significance level		0.113	0.715	0.849	0.584	
NH <sub>4</sub> +NO <sub>3</sub> (kg/ha)	Fire	0-5 cm	3.72ABa	2.96Aa	5.00Ba	11.68a	<b>0.032</b>
	Control		3.08Aa	2.80Aa	5.27Ba	11.15a	<b>0.001</b>
	Significance level		0.306	0.779	0.727	0.498	
NH <sub>4</sub> (kg/ha)	Fire	5-10 cm	1.50Aa	1.49Aa	3.2Ba	6.19a	<b>0.000</b>
	Control		1.45Aa	1.66Aa	3.16Ba	6.27a	<b>0.000</b>
	Significance level		0.915	0.448	0.893	0.578	
NO <sub>3</sub> (kg/ha)	Fire	5-10 cm	1.52Aa	1.44Aa	2.79Aa	5.75a	0.058
	Control		2.33Aa	1.61Aa	3.84Ba	7.78a	<b>0.000</b>
	Significance level		0.176	0.523	0.113	0.096	
NH <sub>4</sub> +NO <sub>3</sub> (kg/ha)	Fire	5-10 cm	3.02Aa	2.93Aa	5.99Ba	11.94a	<b>0.003</b>
	Control		3.78Aa	3.27Aa	7.00Ba	14.05a	<b>0.000</b>
	Significance level		0.389	0.430	0.201	0.128	

At a depth of 5-10 cm, ammonium mineralization was revealed to be low in the fire areas, as at a depth of 0-5 cm. When the temporal change was analyzed, it was determined that the amount of ammonium decreased in the first measurement period, decreased in the second measurement period, and slightly increased in the third measurement period with the fire compared to control areas. Concerning this change in nitrate values, there was a decrease in all three measurement periods. Total mineral nitrogen values were



determined to be higher in the control area compared to the fire area. The temporal change in the fire areas was found to be statistically significant in ammonium and nitrate values, as at a depth of 0-5 cm ( $P < 0.05$ ). The difference between all mineral nitrogen data in the burned and unburned areas was found to be insignificant in all periods ( $P > 0.05$ ).

The values of nitrogen mineralization per hectare in the burned and unburned areas are presented in *Table 4*. According to these values, the ratio of nitrate to ammonium was found to be higher than 1 in the fire area at a depth of 0-5 cm. However, it was determined to be low in the control area. At a depth of 5-10 cm, it was greater than 1 in the control area and less than 1 in the fire area. At a depth of 0-10 cm, these ratios were calculated to be 1.08 and 0.98 in the unburned area and burned area, respectively. Nitrification values also revealed similar results. At a depth of 0-10 cm, while annual ammonium mineralization values were 11.93 kg/ha and 12.14 kg/ha in the burned area and unburned area, respectively, nitrate mineralization values were 11.69 kg/ha and 13.06 kg/ha, respectively. Finally, the total mineralization values were 23.56 kg/ha and 25.20 kg/ha, respectively. Based on these results, it was observed that mineralization values decreased with the fire.

**Table 4.** Net mineralization and nitrification values and ratios in soils

Depth (cm)	Parameter	Control	Fire	Parameter	Control	Fire
0-5	NH <sub>4</sub> (kg/ha)	5.87	5.74	NH <sub>4</sub> (mg/kg)	12.04	12.62
0-5	NO <sub>3</sub> (kg/ha)	5.28	5.94	NO <sub>3</sub> (mg/kg)	11.10	12.79
0-5	NH <sub>4</sub> +NO <sub>3</sub> (kg/ha)	11.15	11.68	NH <sub>4</sub> +NO <sub>3</sub> (mg/kg)	23.14	25.41
0-5	NO <sub>3</sub> /NH <sub>4</sub>	0.90	1.03	NO <sub>3</sub> /NH <sub>4</sub>	0.92	1.01
0-5	NO <sub>3</sub> /NH <sub>4</sub> + NO <sub>3</sub> *100 (%)	47	51	NO <sub>3</sub> /NH <sub>4</sub> + NO <sub>3</sub> *100 (%)	48	50
5-10	NH <sub>4</sub> (kg/ha)	6.27	6.19	NH <sub>4</sub> (mg/kg)	11.43	11.42
5-10	NO <sub>3</sub> (kg/ha)	7.78	5.75	NO <sub>3</sub> (mg/kg)	14.13	10.69
5-10	NH <sub>4</sub> +NO <sub>3</sub> (kg/ha)	14.05	11.94	NH <sub>4</sub> +NO <sub>3</sub> (mg/kg)	25.56	22.11
5-10	NO <sub>3</sub> /NH <sub>4</sub>	1.24	0.93	NO <sub>3</sub> /NH <sub>4</sub>	1.24	0.94
5-10	NO <sub>3</sub> /NH <sub>4</sub> + NO <sub>3</sub> *100 (%)	55	48	NO <sub>3</sub> /NH <sub>4</sub> + NO <sub>3</sub> *100 (%)	55	48
0-10	NH <sub>4</sub> (kg/ha)	12.14	11.93	NH <sub>4</sub> (mg/kg)	23.47	24.07
0-10	NO <sub>3</sub> (kg/ha)	13.06	11.69	NO <sub>3</sub> (mg/kg)	25.23	23.48
0-10	NH <sub>4</sub> +NO <sub>3</sub> (kg/ha)	25.20	23.56	NH <sub>4</sub> +NO <sub>3</sub> (mg/kg)	48.7	47.55
0-10	NO <sub>3</sub> /NH <sub>4</sub>	1.08	0.98	NO <sub>3</sub> /NH <sub>4</sub>	1.07	0.98
0-10	NO <sub>3</sub> /NH <sub>4</sub> + NO <sub>3</sub> *100 (%)	52	50	NO <sub>3</sub> /NH <sub>4</sub> + NO <sub>3</sub> *100 (%)	52	49

As a nitrogen mineralization values were calculated in mg/kg, while the total annual values were 24.07 mg/kg and 23.47 mg/kg in the burned area and unburned area, respectively, in ammonium at a depth of 0-10 cm, they were 23.48 and 25.23, respectively, in nitrate and 47.55 and 48.70 mg/kg, respectively, in total mineralization values. In the evaluation of mineralization values in mg/kg, it was observed that ammonium mineralization increased, and nitrate and total mineralization decreased with the fire at a depth of 0-10 cm. However, it was revealed that all three mineralization components increased with the fire at a depth of 0-5 cm.

## Discussion

There have been some increases and decreases in the sand, clay and silt values examined in the texture measurements performed in the soil after the fire. However, this alteration was not statistically significant. In many studies, it was concluded that there might be a difference in texture values with the breakdown of soil particles under high temperatures (Iglesias et al., 1997; De Bano et al., 1998; Hubbert et al., 2006; Chief et al., 2012). On the other hand, some researchers stated that there was no significant change in the texture structure of the fire in low-intensity fires (Granged et al., 2012; Scharenbroch et al., 2012). In the presented study, the low fire intensity confirms the findings obtained with a literature study.

Soil pH values were analyzed; they were revealed to be higher in the topsoil in the fire area compared to the control area. In many studies, it was indicated that the soil pH value increased after the fire, especially in the topsoil (Certini, 2005; Küçük, 2006; Ekinci, 2006; Scharenbroch et al., 2012; Berber et al., 2015; Muqaddas et al., 2015; Kong et al., 2019). In this study, the effect of fire on pH was not found to be statistically significant, which can be attributed to the very low intensity of the fire. Some researchers stated that the effect of fire on pH was statistically insignificant, as in the presented study (Switzer et al., 2012; Meira-Castro et al., 2014; Alcañiz et al., 2016; Valkó et al., 2016; Lucas-Borja et al., 2020).

Soil organic matter values were examined; it was observed that the effect of the fire was insignificant. The reason for it may be the low severity of the fire because changes in soil properties in low-intensity fires were less. However, in many studies, it is indicated that the fire has a significant effect on the soil organic matter (Johnson and Curtis, 2001; Choromanska and de Luca, 2001; Six et al., 2002; Muqaddas et al., 2015; Alcañiz et al., 2016). On the other hand, in some studies, researchers stated that the effect of forest fire on soil organic matter change was insignificant (Gundale et al., 2005; Lavoie et al., 2010; Valkó et al., 2016). While the soil organic matter values in the fire area were higher in the first six months after the fire compared to the control area, they were found to be lower at later times. When the overall averages were evaluated, the amount of organic matter in the fire area was found to be slightly higher compared to the control area.

The total nitrogen values in the fire area were determined to be close to each other in the first six months after the fire. Then, there was a serious decrease in the fire area. Some researchers stated that, the fire decreased nitrogen in the soil (Dzwonko et al., 2015; Muqaddas et al., 2015; Francos et al., 2019). Based on the statistical evaluation, the effect of the fire on total nitrogen was revealed to be insignificant. However, in many studies, it was concluded that the fire played an increasing role in total nitrogen in the soil (Knoep and Swank, 1993; Johnson and Curtis, 2001; Knoep et al., 2004; Scharenbroch et al., 2012; Alcañiz et al., 2016).

It was observed that the fire generally played an increasing role in the carbon/nitrogen ratio. The effect of the fire on nitrogen and carbon-nitrogen ratio was also found to be statistically significant. In some studies, it was reported that the C/N value increased after the fire (Gundale et al., 2005; Scharenbroch et al., 2012), which is considered to be due to the fact that the increase in organic carbon in the soil after the fire led to an increase in the C/N ratio. Likewise, in the correlation analysis, the fact that we found a negative correlation between the C/N and total nitrogen supported this statement.

The bulk density values at both depths were revealed to be lower in the fire area in comparison with the control area. However, this low value was not statistically significant. It could be said that the low bulk density in the fire area was caused by higher

organic matter and ash content in the fire areas. High organic matter decreases bulk density. The effect of time on bulk density was also determined to be insignificant both in the fire area and in the control area. In some studies, researchers stated that bulk density decreased after the fire (Brye, 2006; Chief et al., 2012; Mastrolonardo et al., 2015).

Ammonium mineralization showed lower values in the fire area at a depth of 0-5 cm after the fire compared to the unburned areas, it exhibited higher values at a depth of 5-10 cm. At a depth of 0-10 cm, this value was also found to be higher in the control areas. However, it was revealed that this alteration was not statistically insignificant. Since the measurements were made on a hectare basis, changes, especially in bulk density and soil moisture content, affected these values because this change was found to be more different in the mg/kg measurement units of ammonium mineralization. Especially at a depth of 0-5 cm, ammonium mineralization values were determined to be higher in the burned areas compared to the unburned areas. The fact that the fire in the study area was in the form of a low-intensity surface fire also appeared to play a determining role in this effect. The effect of the fire occurred more significantly at a depth of 0-5 cm. The effect of time on mineralization was found to be significant. Changes in soil temperature, soil moisture, soil pH and soil organic matter, and therefore, changes in the C/N ratio over time can be shown as the factors causing it because these variables change the amount of ammonium in the soil. The periodic change of organic matter in the fire area influences mineral ammonium. The removal of litter on the soil surface in the fire areas could affect the net mineral ammonium values in seasonal changes in soil moisture. In general, the net ammonium yield and nitrate yield are high in moist soils and dry soils, respectively (Anggria et al., 2012).

Mineral nitrate yields were identified to be higher in the fire areas at a depth of 0-5 cm and in the control areas at a depth of 5-10 cm. These measurements were calculated on a kg/ha basis. However, this difference was found to be statistically insignificant. The results obtained when the measurements were evaluated on an mg/kg basis did not change the outcome of these changes a lot. Nitrate mineralization on an mg/kg basis occurred in the fire area at a depth of 0-5 cm and in the control area at a depth of 5-10 cm. Therefore, the degree of influence of the fire was also limited at a depth of 0-5 cm. In particular, nitrate mineralization is associated with pH values. Nitrification events in the soil increase as pH increases. It is indicated by some researchers that the nitrate content increases as pH increases (Robinson, 1963; Black, 1968; Sahrawat, 1982; Lopez and Martin, 1995; Paul and Clark, 1996; Neary et al., 1999; Anggria et al., 2012). In their study, Mikita-Barbato et al. (2015) found that the amount of nitrate in the fire areas was higher compared to the control areas. Fernandez-Fernandez et al. (2015) revealed that the mineral nitrate values in the fire area on a kg basis were lower compared to the control area. As a reason for it, they indicated the high intensity of the fire. Low fire intensity in our areas may not affect microorganism activities too much. The fact that organic matter is easily decomposed by microorganisms and reaches the appropriate pH environment enables us to find the nitrate yield in the fire areas in this study higher compared to the control areas. There was also a linear relationship between the amount of organic matter in the soil and nitrogen content mineral nitrate yield. High organic matter plays an increasing role in nitrate mineralization. It is considered that the fact that the organic matter in the fire area was found to be high also led to an increase in the amount of mineral nitrate.

The effect of time on total net mineralization data was determined to be significant both in the fire area and in the control area. As a reason for it, it is considered that

properties such as changes in temperature and precipitation conditions within the periods and changes in microorganism activities and physiological activities of plants explained this difference. It is also considered that different properties such as organic matter, pH nitrogen, and C/N between periods led to this difference. In many studies, it was determined that organic matter, total nitrogen, and C/N value were associated with the total net mineralization values. In various studies, it was also concluded that nitrogen mineralization increased after the fire (Kovacic et al., 1986; Kaye and Hart, 1998; Knoepp and Swank, 1993; Hamman et al., 2008). The researchers attributed this increase to the combustion products, evaporation of organic nitrogen from the soil surface, microorganism activities in the soil, and changes in pH, soil temperature, and moisture in the soil (Blair, 1997; Knoepp et al., 2004).

## Conclusions

As a result of this study, the results of one-year period on the soil properties and biological activities of the fire in the region where red pine grows under extreme growing conditions were evaluated. Since the fire severity is low and it is out of the fire season at the time of the fire, the impact of the fire on the soil properties did not emerge at statistically significant levels. In order to reveal the effect of fire on nitrogen mineralization, especially in red pine ecosystems, it can be investigated by experiment fires with different fire intensities and its effects on soil properties. Again, regional differences can be revealed by planning trial fires in the Mediterranean Region and Black Sea Region in the same period. Again, according to the results of this study, considering that the fire increases the soil pH, organic matter and mineralization amounts, it can facilitate rejuvenation activities by making it easier for the seed to reach the soil by going to cover fire studies, especially during abundant seed years.

Prescribed fire practices ensure that nutrients kept in the litter are transferred to the soil, especially in areas with low litter decomposition. In this way, the seed is provided to reach the soil, and germination and sapling development are positively affected in rejuvenation studies. Practitioners can easily achieve this goal by applying low density cover fire applications in such areas. By performing these applications at regular intervals, an increase in the accumulation of substances, which will trigger the fire, can be prevented. In this way, the possibility of a fire is reduced during periods of intense fire risk.

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